



## SMALL BUSINESS INNOVATIONS

A steadily growing source of aerospace spinoff applications is the Small Business Innovation Research (SBIR) program, which was established by Congress in 1982 with dual objectives: to increase participation by small businesses in federal R&D activities, and to stimulate conversion of government funded research into commercial applications.

NASA is one of 11 technology-generating agencies of the federal government participating, each administering its own programs independently under policy guidelines set by the Small Business Administration.

Among recent examples of successful SBIR commercialization is the PER-Force handcontroller shown **at right**, a force-reflecting system that manipulates robots or objects by "feel." Originally developed for the International Space Station under a Johnson Space Center SBIR contract, the handcontroller is produced by Cybernet Systems Corporation, Ann Arbor, Michigan. Headed by president Heidi Jacobus and her husband, Dr. Charles Jacobus, Cybernet began life in 1988 as a cottage industry

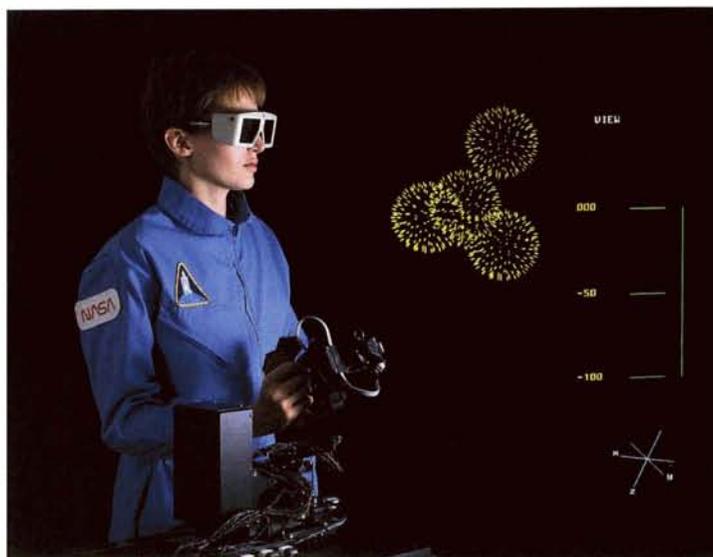
and has grown to a work force of 25; the company has worked on 16 SBIR projects and still does most of its business with government agencies, but is making gradual inroads in the commercial market.

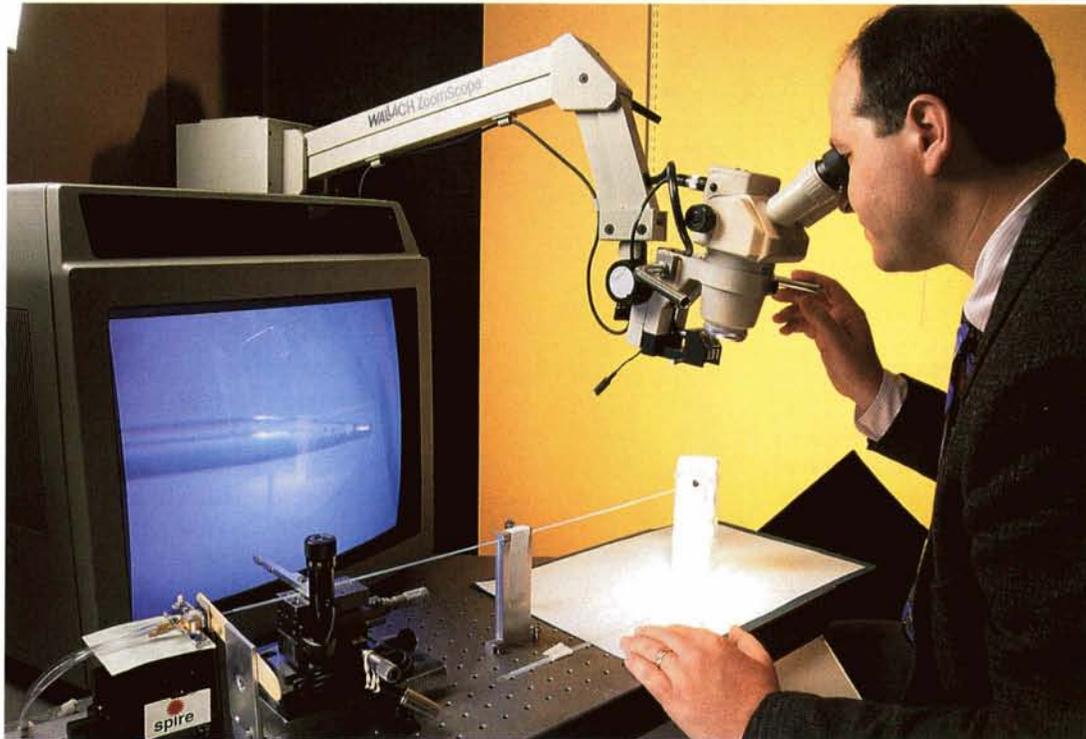
Cybernet's original NASA contract called for development of a teleoperation device with force feedback that would allow a space station astronaut to position an external robot arm. When the arm encountered an outside force, the robot control stick would represent that force by making motors built into the joystick push or pull or twist to represent the reality of the outside world. The intent was to improve teleoperator performance by providing the sense of feel.

In the course of developing the NASA system, Cybernet found it necessary to go beyond representing only real forces, and to include

virtual reality representations. "Since then," says Dr. Charles Jacobus, who is vice president and technical director, "we've discovered that the flexibility incorporated into the control system for building virtual force fields has opened up a whole new dimension in man-machine interface for complex visualization applications." The device is particularly well-suited for teleoperator environments where direct viewing is limited, for example, in murky underwater environments or reduced light areas such as underground excavations.

The commercially available PER-Force Handcontroller is a small, back-driveable robot handle that moves in six degrees of freedom, including 3-D positions (x, y, z) and three attitudes (roll, pitch and yaw). The operator uses the motorized handle to precisely position





robots and graphically displayed objects at a given location and tool angle. Among current applications, it is being used for molecular modeling in metallurgy applications, in satellite docking research, and in research on military unmanned ground vehicles. Real and virtual reality forces are simulated by a 3-D molecular modeling software package that calculates the interacting forces among attracting and repelling molecules; those forces are represented through the robot stick.

Cybernet has used the original SBIR work as a departure point for a whole family of force reflective devices in the telepresence and virtual reality fields, and has developed and patented a general interface architecture for integrating visual and tactile displays.

Another example of SBIR success is the commercialization of high power diode laser arrays, developed

under Langley Research Center SBIR funding, by Spire Corporation, Bedford, Massachusetts. Langley's principal interest in diode laser arrays was their potential for use in LIDAR (light detection and ranging) devices in wind-shear detection and warning systems. A Langley developed windshear system employs an optical laser telescope to send light beams ahead of an aircraft into a storm; measurement of the energy reflected back to the telescope from particles in the storm provides an indication of windshear.

The NASA contract with Spire called for development of a high power semiconductor diode laser module to pump solid state laser rods or slabs. This type of module, as a replacement for the normally used flashlamp, offers a number of advantages: highly efficient optical pumping, very small size, low drive voltage requirements, and extended operational lifetimes.

Spire Corporation successfully developed the laser array for NASA and used the NASA work as a development base for a commercial line of diode laser arrays for industrial and other uses. **Above**, Dr. Joel S. Schuman investigates a high power pulsed diode laser at Tufts University School of Medicine, Medford, Massachusetts. The laser delivers its light through a thin fiber optic cable. Among applications are laser sclerectomy, an operation to reduce glaucoma-caused eye pressure. The products can also be used in industrial cutting and drilling and in military applications. Spire Corporation's Dr. Kurt J. Linden, manager of laser product development, reports that the high efficiency of the products has brought rapidly increasing demand for diode laser pumps.

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Langley Research Center has been engaged for more than a decade in development of advanced polymers, used in foams, fibers, adhesives, composites and coatings for a variety of space applications. The Center is among the world leaders in developing these chemical compounds, and Langley sponsored advances have contributed significantly to improving the U.S. competitive posture in polymer production and application.

Langley, however, is an R&D organization, so it looks to industry to commercialize the Center-invented polymers, identify commercial applications in and beyond the aerospace field, and develop cost effective ways of producing them. This is accomplished by partnerships with industry firms under Small Business Innovation Research (SBIR) contracts.

An example is the collaboration of Langley with Triton Systems, Inc. (TSI), Chelmsford, Massachusetts. TSI is an innovative high technology company specializing in R&D and technology transfer leading to product development. The company develops niche products in high performance polymers, advanced ceramics, metal matrix composites and flexible manufacturing processes.

A major need for the International Space Station and



future long-duration space structures is a polymer resistant to atomic oxygen (A/O), which exists in low Earth orbit and causes corrosion of spacecraft surfaces. Langley researchers invented a promising high performance polymer known as PAEBI to meet that need. Under an SBIR contract, TSI took the PAEBI polymer from laboratory scale to pilot scale, identified several niche market opportunities, and formed a partnership with a leading polymer film processing firm. TSI was granted a license for commercial development of the PAEBI-based polymer, now known as AORIMIDE®

(Atomic Oxygen Resistant Imide), and the company also developed the processing techniques needed to coat long runs of high quality continuous films of AORIMIDE.

TSI subsequently received three other SBIR contracts, each geared toward a different AORIMIDE-based product. TSI now offers the product in four forms: AORIMIDE polymer in pound quantities for commercial uses; AORIMIDE free standing films for space systems and for Earth use in electronics and electrical insulation applications; ultrahigh performance polymer threads based on AORIMIDE chemistry for space applications; and AORIMIDE co-polymer material for use as membranes in elevated temperature separation applications (it is in use by a major membrane manufacturer as a liquid separation medium). **Above**, Triton president Ross Haghghat displays one of his



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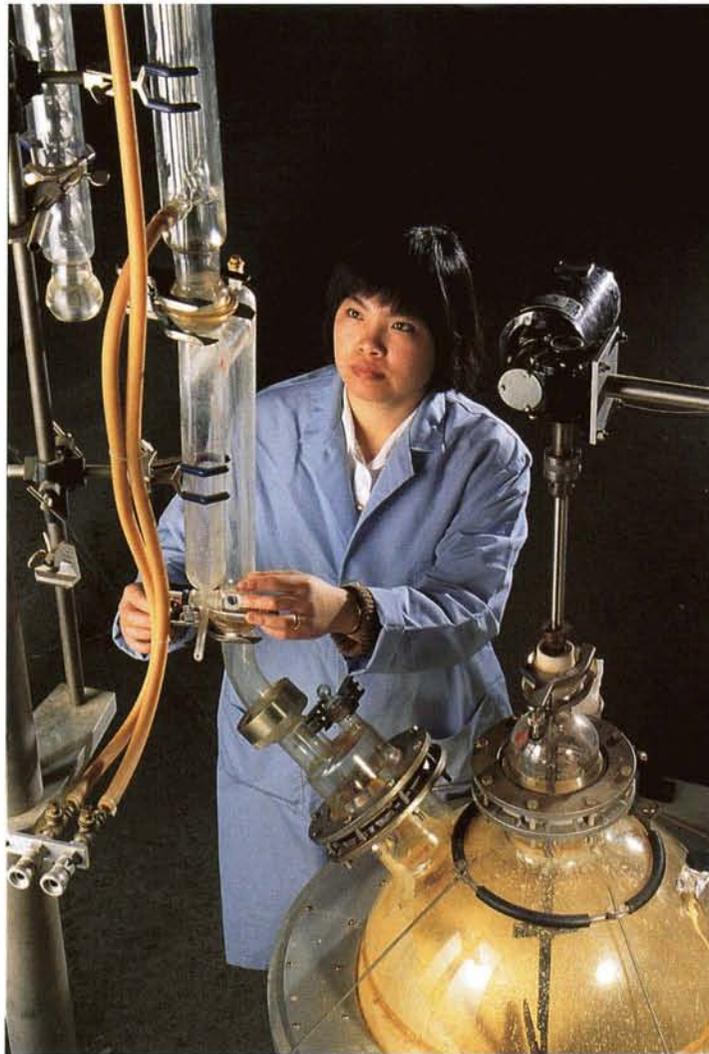
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products, sheet polymer rolled into a core; other products including powder, liquid, and polymer sheet, are shown **at left below**.

Another small business that has worked effectively as a Langley partner is Imitec, Inc., Schenectady, New York. As the company name suggests, Imitec focuses its efforts on polyimides, polymers that can tolerate high temperatures without deforming. Imitec has received several SBIR contracts to modify, characterize and commercialize Langley-invented polyimides.

Imitec developed its own processes to produce the Langley materials, processes that make possible fiber quality material, film quality material and moldable material. Under a Langley SBIR contract, Imitec teamed with Barcel Wire and Cable, Irving, California in a successful project involving development of polymer pelletizing and extrusion technology and its application to manufacture of insulated aircraft cable. Imitec is also collaborating with AlliedSignal, Hoosick Falls, New York on use of NASA polyimides in flexible circuitry.

**Above**, Imitec chemist Betty Chung is making the material in a reactor; **at right** is a sampling of products made from the material, including high temperature gears, polymer in sheets,



polymer in bead form, and temperature resistant light-weight brick or tile forms.

Imitec has installed a reactor, centrifuge, film casting equipment, drying ovens and additional electric power to continue commercialization of the NASA polymers. The company has also developed processes to manufacture monomers and installed a pilot reactor to continue development. Imitec is supplying developmental quantities of powder or liquid poly (amic acid) to such customers as Lockheed Martin, Northrop Grumman and ICI-Fiberite for aerospace composites and optics; Cytec Industries, The Boeing Company and 3M Corporation for use in adhesives; IBM and Motorola for electronic systems; Ford Motor Company



and Delco-Remy GM for automobile applications. Imitec is also working with Lockheed Martin and Rockwell International on using Langley invented polymers in the NASA X-33 launch vehicle development program.

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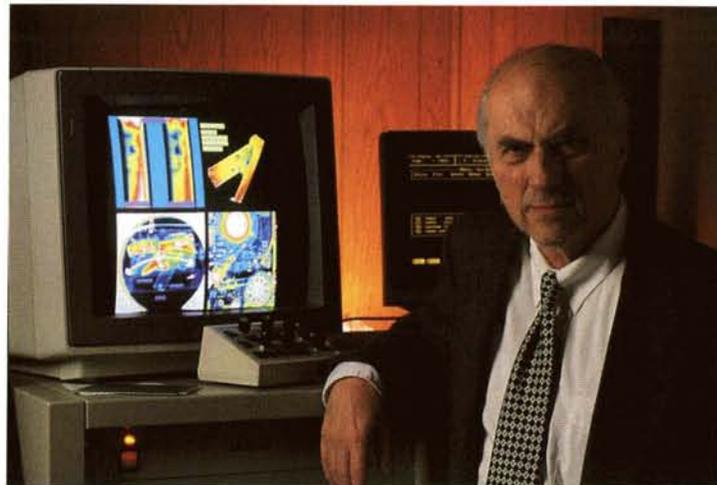
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NASA's Langley Research Center was looking for a way to improve the process of inspecting aging aircraft without taking the planes apart. They found it in a novel concept — originated by Richard Albert (**right**) and developed by his company, Digiray® Corporation, San Ramon, California — called reverse geometry x-radiography (RGX)®. RGX employs a combination of television-like scanning and digital data acquisition to produce real-time x-rays with film quality.

Since the discovery of x-rays in 1895, radiographers have employed a small point source and a large detection area. This conventional configuration allows some degradation of image quality as the detection medium registers the secondary radiation (x-ray scatter) produced in the object being bombarded by radiation.

RGX reverses the conventional configuration. The object to be x-rayed is placed adjacent to a large source whose raster scan is picked up by a distant detector. In this approach, much of the unwanted scatter generated in the object is absorbed by the intermediate air before it can reach the remote detector. The result is improved image clarity and better inspection throughput, with



four times the contrast sensitivity of conventional systems.

Under two Small Business Innovation Research (SBIR) contracts, Digiray teamed with Langley researchers of the Center's Nondestructive Evaluation Sciences Branch (NESB) to develop a portable RGX system (portability is a necessity for field inspection of aircraft), and to upgrade the x-ray energy of the system so that thicker parts could be x-rayed. The SBIR work involved miniaturization of the system's sensors so they could be inserted into internal aircraft structures, such as hard-to-get-at corners and crevices. The project gave Langley a device that can be used not only for aircraft inspections, but for assessing damage growth in materials, for supporting tests to show how structures behave under stress, and for monitoring changes in solid

rocket fuel over time.

The Digiray project was part of a still-ongoing seven year Langley program that is exploring ways to conduct thorough examinations of aircraft without disassembling them by means of advanced inspection techniques, including ultrasound and thermography in addition to x-ray.

Digiray further developed the technology under separate arrangements with the U.S. Air Force, the Department of Energy's CEBAF (Continuous Beam Accelerator Facility) and Lawrence Livermore National Laboratory.

The RGX produces x-ray images by means of a scintillating crystal detector in which a number of tiny crystals light up when excited by x-ray beams, creating an image that is computer processed into a digital x-ray. The image can then be enhanced by standard image processing tools, such as

averaging, filtering, image subtraction and edge enhancement. **At right**, a helicopter tail rotor is undergoing inspection by Digiray to find delamination and stress cracks; **below**, a Digiray image shows corrosion in an airplane wing assembly.

The feasibility of using the RGX system for computed tomography, which provides cross-sectional x-ray images, has been demonstrated. With the RGX, an entire family of cross-sectional images can be obtained during a single revolution of an object.

The RGX is being used by the Air Force to x-ray parts of fighter aircraft, and by McDonnell Douglas Corporation in a comparison study of RGX versus ultrasound inspection of composite aircraft structures. The portability of the system has led to applications in areas other than aerospace, for example, inspection of pipes corroding under insulation at oil refineries, which has been

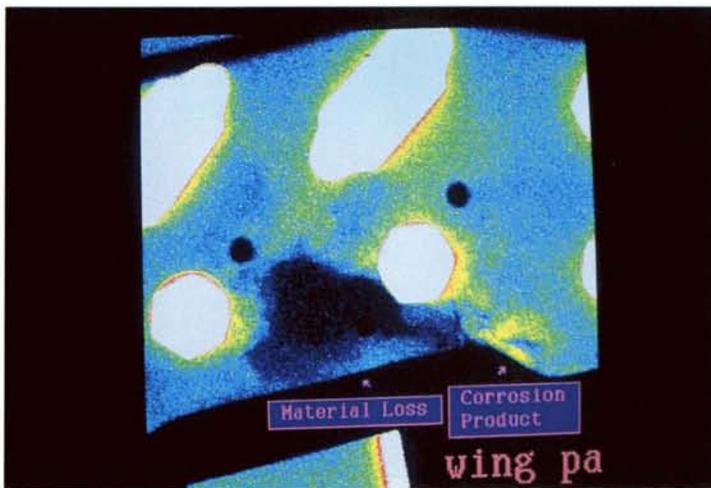
identified as a cause of serious refinery fires; **at right** is an image showing thinning in the walls of a refinery pipe section. Mobil Oil Corporation, Exxon and Shell Oil are conducting tests of the Digiray system.

A related product that emerged from the Langley work is the company's patented RGL (reverse geometry laminography) system that provides layer-by-layer x-ray viewing with only one exposure. A demonstration of the RGL showed the system's ability to image both sides of a quarter — the Washington head and the eagle tail — with a single exposure. The clarity of the



imagery suggests that the system can enhance current imaging techniques in such areas as mammography, cardiac imaging, brain surgery and orthopedics.

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\*RGX, Reverse Geometry X-rays and Digiray are registered trademarks of Digiray Corporation.

Continually looking for new ways to shave weight and improve the structural integrity of Space Shuttle components, NASA awarded several Small Business Innovation Research (SBIR) contracts to Nichols Research Corporation (NRC), Huntsville, Alabama for development of an advanced system to weld segments of the 154-foot-long Space Shuttle External Tank. NRC successfully developed such a system and commercialized the technology with the marketing of a device known as Wire Pilot™.

Essentially a small robot, the Wire Pilot (**below**) is a programmable, motorized three-axis manipulator for precise positioning of filler wire relative to the welding torch and workpiece. Designed to automate the placement of filler wire during precision automatic and robotic welding, the wire manipulator is housed in a compact, rugged, nine-inch package that accepts standard wire feeder guide tips. A hand-held unit (**right**) enables control of the filler wire entry angle, the force against the workpiece, and

the offset from the weld centerline. The controller electronics are shown **at lower right**.

A miniature load cell built into the wire guide tip assembly senses the force between the workpiece and the filler wire, and closed loop control drives the motors to keep this force constant, thus maintaining a constant force between the filler wire and the workpiece regardless of automatic voltage control (AVC) adjustments or reactions to condition changes. The load cell output can also be used as an AVC feedback

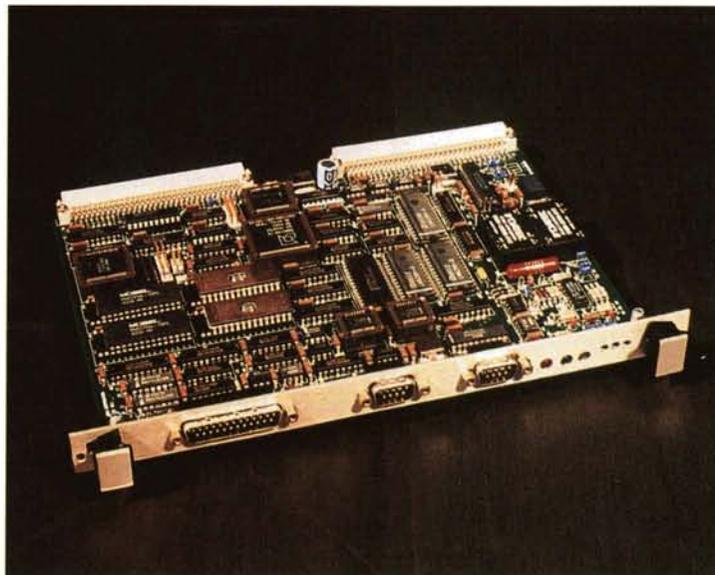




signal to provide constant torch-to-wire distance.

The Wire Pilot employs a unique configuration of three linear drives to achieve high precision three-axis coordinated motion. The three axes of motion are the X axis (side-to-side), the Y axis (in/out), and the Z axis (angle change). The Z axis rotates about an operator-defined toolpoint that is programmed to the location where the wire enters the weld pool. This prevents angle changes from affecting the force on the wire pressure load cell.

Because operator or equipment malfunctions can cause the unit to be crashed into the workpiece, a two-stage crash protection system is built into the device. For slight crashes, a spring on the upper drive rod flexes, allowing the tip to rotate without sustaining damage. In more severe crashes, the entire unit slides backward up to one inch on its base plate without damage. It is



spring loaded to return to its normal position.

The Wire Pilot was developed as a stand-alone system or as part of a VME-based control system. The stand-alone system consists of the wire manipulator, the controller and an operator's pendant. The controller board can be integrated directly into VME-based systems.

Marshall Space Flight Center managed the SBIR contracts and engineers/technicians of Marshall's Materials Processor Branch assisted NRC throughout the development of the system.

<sup>TM</sup>Wire Pilot is a trademark of Nichols Research Corporation.

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